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Ceteris paribus, spatial complexity and spatial equilibrium An interpretative perspective

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Abstract

This paper addresses the implications of the well-known *ceteris paribus* postulate for spatial–economic equilibrium analysis under conditions of complex (non-linear dynamic) interactions in open systems. Under ever changing (*e.g.*, evolutionary) conditions, there is a need for adjusting the standard tools in spatial–economic analysis, with more emphasis on evolutionary algorithms and computer simulations to offer a solid statistical underpinning of regional analysis.

Keywords: *Ceteris paribus*; Complexity; Counterfactuals; Equilibrium; Evolutionary models; Networks; Spatial interaction; Value transfer

1. A new challenge

The space–economy is often interpreted as a standard well-functioning economic system enriched with the element of space. But space is not just an additional dimension of the economy; it forms an intrinsic feature of any geographic–economic system and leads to the emergence of complex non-linear and interactive behaviours and processes in space. A fascinating foundation for an interpretation of the space–economy as an interdependent complex set of economic relationships – at different geographic scale levels and with a variety of time dimensions involved – can be found in the first law of geography formulated by Tobler (1970) who stipulates that everything in space is related to everything else, but near things are more related than distant things. The depth of this law has received

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insufficient attention in the methodology of regional economics – and geography as well – and needs to be reconsidered in the light of recent advances in complexity theory. This short paper aims to highlight some implications of modern complexity theory for regional analysis.

The very heart of reductionist and deductive thinking in economics – including regional economics – lies in the standard tool of economic analysis, namely the *ceteris paribus* postulate. Section 2 is devoted to a critical review of this concept and prompts the question on the validity of this concept in spatial–economic interaction. This issue is further highlighted in Section 3 from the perspective of open systems. The next section (Section 4) introduces the principal elements of complexity theory against the background of non-linear evolutionary approaches to the space–economy. Then the question arises what the relevance is of spatial economic equilibrium in the context of complex spatial systems when such systems are investigated under *ceteris paribus* assumptions. Section 5 is devoted to this fundamental problem. This issue creates obviously a research dilemma that calls for a novel methodology for quantitative analysis of regional economic phenomena. Section 6 provides some tentative pathways for alternative research lines on this methodological challenge, while it concludes with some retrospective and prospective ideas on future challenges faced by regional economic analysis.

2. *Ceteris paribus* and the space–economy

Scientific research means a fascinating discovery tour through an unknown complex world. In the search for generalisable knowledge applicable to other places, persons or times (reflected *inter alia* in the so-called value transfer question), it has become usual in economics to introduce simplifying assumptions so as to cope with place-specific, subject-specific or time-specific conditions. This implies essentially a reductionist approach by focussing attention on a few selected distinct features of a complex reality that serve as abstract descriptions of salient characteristics to be investigated. In particular the *ceteris paribus* condition has become a central tool in economic research to draw references on commonalities in behaviour of economic subjects or agents by assuming that certain contextual (or environmental) factors may be seen as constant across the objects of research under consideration. Such factors ensure a certain order or structure which allows for transferability (or even generalisation) in an otherwise chaotic world. This methodological approach means essentially an abstraction from a highly varied complex real-world economic system and allows for a focussed – but necessarily restricted – investigation of a certain relevant economic phenomenon in a broader system's context. Such a simplifying approach is formally or logically not strictly needed, but in an empirical system a limitation to a selected set of features is useful in order to distinguish in a consistent way between system-internal and system-external factors. Even though the distinction between system-internal and system-external factors may be somewhat arbitrary, such a simplification is essential in order to arrive at generalized knowledge on the basis of limited system's knowledge. For example, the wealth of current knowledge on complex economic phenomena might never have been achieved without the simplifying hypothesis of a *homo economicus* or its related concept of utility maximization (see Bal and Nijkamp, 2001, 2002).

The notion of interactive behaviours and processes that have emerged from modern complex network theory in open systems (see *e.g.* Capra, 1997; Nijkamp and Reggiani, 1998) challenges clearly the use of *ceteris paribus* conditions (especially in an interdisciplinary research context). However, it is clear that in a complex spatial–economic system we need certain key anchor points for scientific inference on relevant objects of research. From this perspective the *ceteris paribus* clause is a cornerstone for a deductive empirical economic discipline (see Störig, 1959; Rivett, 1970; Glymour, 1992).

It is noteworthy that the *ceteris paribus* condition has a long history. Persky (1990) even claims that its earliest use in its current meaning dates back to the year 1311! In any case, it was mainly Marshall (1898) who introduced this postulate in modern economic thinking. He needed essentially a reduction of a complex economic world for his partial equilibrium analysis, so as to demarcate a restricted economic research domain. Clearly, later on it turned out that a general equilibrium model (see *e.g.* Arrow and Debreu, 1954) needed less restrictive contextual conditions, but also here definitely certain external conditions had to be taken for granted.

The *ceteris paribus* clause assumes away interactions with the external world, so that by definition any economic analysis is at best based on partial cause–effect relationships. By necessity we are then confronted with a black-box situation which cannot be satisfactorily and completely tackled by the research effort regarding the phenomenon concerned. The *ceteris paribus* condition is particularly interesting in the context of the space–economy where according to Tobler's law (see Tobler, 1970) everything is related to everything else, albeit to a varying degree according to distance. This contradiction will be taken up further in Section 3, where spatial–economic interaction will be addressed.

3. Spatial interaction in open systems

The space–economy is an interactive system with varying degrees of openness of economic flows (movement) of people, goods or information. The dynamic interactions between the components of a spatial system are functionally determined by interdependencies between the behaviour of actors and distance frictions, as indicated by the above mentioned first law in geography. Such spatial interactions may be stable in nature (*i.e.*, operating under fixed external conditions) or subject to change as a result of dissipative evolutionary processes in the external world. In the latter case, model parameters become time-dependent, so that nonlinear complex dynamics may emerge (see Puu, 1991; Zhang, 1991; Nijkamp and Reggiani, 1998). In addition, connectivity in complex network structures (*i.e.*, qualitative patterns of interaction) may impact on the dynamics of the economic variables under investigation. This may result in discontinuous changes, asymmetric behaviour or, in general, unstable evolutionary patterns. The mathematical–statistical problems associated with nonlinear dynamic modelling have for a long period meant an obstacle to an operational analysis of such phenomena in the social sciences, but advanced computational methods have in recent years allowed researchers to deal with structural changes in complex models, including spatial–economic complexity.

Nevertheless, research into nonlinear dynamic modelling of interrelated phenomena in a complex dynamic system is far from easy. Especially in economics we usually face a situation where the behaviour of actors impacts on external environmental conditions, which causes a conflict with standard *ceteris paribus* postulates. More holistic approaches may then be desirable, but any shift in the system's boundaries leads again to the identification problem of new system's boundaries. Evolutionary principles may in principle be helpful here, but data problems tend to hamper a full-scale operational analysis of a complex economic system. A nonlinear complex space–economy adds even to the problem of analysing such phenomena in an empirical world (see *e.g.* Prigogine and Stengers, 1984). For example, an old and depressed industrial district with an outdated technological infrastructure may run into a situation of serious economic decay causing a high socio–economic stress, from which it might recover by actively developing innovative types of labour specialization or institutional reforms, sometimes even at a different geographic scale level. This example demonstrates that in an evolutionary perspective the handling of system's boundaries become very problematic.

Spatial systems are, in general, in principle open systems that exhibit various types of interaction, both short-term and long-term. And policy instruments implemented to serve respectable policy goals have to take into consideration the different time horizons and geographic dimensions of spatial–economic variables. Especially in our modern world, we witness an increasing spatial interdependency as a consequence of the emergence of network structures with both centripetal and centrifugal forces – in different network typologies – which may cause a variety of complex behaviour in a spatial–economic system (see Nijkamp and Reggiani, 1993, 2006). The usage of networks (*i.e.*, the demand side) may show rapidly fluctuating patterns (*e.g.*, flows in transportation systems), but the architecture and design of networks (*i.e.*, the supply side) may exhibit slow dynamics with a long-term structuring impact on the behaviour of a system. This calls once more for a thorough reflection on the question what the external (fixed) conditions of a spatial–economic system are. In this context, evolutionary and ecologically-based systems have increasingly come to the fore. They question the relevance of conventional economic paradigms based on the *ceteris paribus* clause, but prompt also various new research questions related to the dynamics of a spatio–economic network system. Against this background, we will in the next section (Section 4) address briefly the foundations of modern complexity theory, followed by a concise review of spatial–economic equilibrium analysis.

4. Spatial–economic complexity

Complexity theory has in recent years become a major methodological paradigm for many disciplines, in both the natural sciences and the social sciences. Complex systems have – often unpredictable – evolution trajectories that are characterized by non-linear dynamic interdependencies among its components. The theoretical foundation of complexity rests essentially on evolutionary theory where competition, adaptive potential and natural selection play a key role (see *e.g.* Kauffman, 1993 or Fontana, 2002). Complexity theory has also invaded economics, *inter alia* in ecological economics, innovation theory, labour market theory, organizational theory and regional economics (see *e.g.* Dosi, 1982; Frenken, 2006; Nijkamp and Reggiani, 1998).

The research field of complexity theory has in the mean time become vast, but the central idea is that perfect prediction based on rational behaviour in complex systems is problematic, due to many uncertainties caused by the simultaneous occurrence of slow and fast dynamics (including path dependency and lock-in behaviour) and system-wide interactions and feedbacks (positive and negative) including learning mechanisms. Earlier contributions can already be found in bifurcation theory, catastrophe theory, chaos theory and synergetics theory. The mathematics involved is not easy, while the statistical analysis of such phenomena (including spatio–temporal autocorrelation) is rather cumbersome (see *e.g.*, de Graaff et al., 2006). A proper specification of non-linear dynamic models is therefore an enormous challenge, an observation already made more than a century ago by the great economist Alfred Marshall who argued that the element of time is the chief difficulty at the centre of almost every economic problem. The proof of the existence of economic equilibria in complex time-dependent empirical systems causes almost insurmountable analysis problems, as solution trajectories become highly sensitive or may exhibit unexpected discontinuities (see *e.g.* Gandolfo, 1996; Nicolis and Prigogine, 1989).

A common feature shared by all complex systems is that they may exhibit a great variety of dynamic behaviour including also unanticipated irregular behaviour, as a result of nonlinear dynamics and different space–time horizons and interactions among learning agents. Will such systems return to their initial stable equilibrium after an external shock or will they remain at a different state after a perturbation? The intellectual response of the research community to such research challenges has been varied. In this context, complementary concepts like resilience and sustainability have gained much popularity (see *e.g.* Common and Perrings, 1992), especially in the framework of social learning mechanisms. Ecologically-based models (such as Volterra–Lotka equations, predator–prey models, chaos models of the May-type, symbiosis models or niche models) have in the past years increasingly invaded economic analysis and they have generated a new class of complex evolutionary models, *viz.* self-organizing systems models (see Nijkamp and Reggiani, 1993). In more recent years, the statistical testing of such models has received much attention.

The behaviour of complex systems may lead to a richer spectrum of dynamic patterns, if the system concerned is characterized by multiple layers and multiple interacting regions. Clearly, the possibility space of solutions of complex systems is so vast that it is only possible to research a small fraction of this space. Hence, the notion of rational (spatial–) economic behaviour in a stable equilibrium under *ceteris paribus* conditions then becomes problematic, an observation made already by Simon (1969) in his behavioural theory on bounded rationality. Stable behaviour based on the assumption of a well defined solution space in an empirical world may then also become rather rare. This may challenge the proposition of traditional spatial–economic behaviour, in particular because (static and dynamic) complexity and connectivity of a spatial–economic network system may cause an enormous variety in dynamics. This issue will be further discussed in Section 5.

5. Principles of spatial–economic equilibrium

Since Marshall, the question of economic equilibrium has been a permanent source of scientific inspiration in economics. Much attention has been focussed on the question under which conditions a formally defined economic system would achieve a well defined and stable solution. The mathematical rigour of these analyses has sometimes overshadowed the intrinsic variation in behaviour or the bounded rational realism of economic agents. Nevertheless, economic equilibrium analysis has been a major source of transparent and solid economic thinking and has formed a necessary foundation for operational tools such as input–output analysis and linear programming. The importance of equilibrium analysis has in recent years been re-emphasized with the emergence of the class of CGE (computable general equilibrium) models, where the modern computational possibilities have been instrumental in providing a necessary empirical basis to abstract mathematical modelling.

Starting with Lösch (1954) and Isard (1956), spatial equilibrium analysis has also achieved a major position in regional economics, which culminated in the seminal work of Takayama and Judge (1973). A review of various advances in spatial equilibrium modelling can be found in Van den Bergh et al. (1996). All these models are able to encompass system-wide effects of the economic behaviour of classes of agents. They are able to deal with multiple sectors and regions, spatial–economic networks and endogenous price formation. They are applied to a wide area of economic research, ranging from international trade to housing markets, from climate policy models to transportation models, and from foreign direct investment modelling to financial markets. In the space–economy, we find *inter alia* spatial (locational) price equilibrium models and general (competitive) spatial equilibrium models. All in all, equilibrium analysis has gained a respected position in (spatial–) economic research. But in a dynamic network context a meta-question becomes relevant: in how far is a spatial–economic equilibrium dependent on a given network structure? This also prompts the question which network morphology is economically efficient. These open questions mean a great challenge to equilibrium analysis.

Complex dynamics poses an enormous challenge to (spatial–) economic equilibrium analysis. Especially evolutionary analysis tends to question the relevance and validity of the strict distinction between internal and external system's conditions; clearly, the elimination of *ceteris paribus* conditions may even render the notion of general equilibrium less meaningful. If the standard assumption in equilibrium models of a well-behaved, transparent and identified functional form of the state equations is omitted, the existence conditions for stable optimal (equilibrium) conditions are violated. Consequently, unforeseen and irregular behaviour inherent in complex systems models leads to nonlinear evolutionary solution trajectories which may challenge standard equilibrium thinking. In the context of 'economics without equilibrium' we refer here to Kaldor (1985) who claims in his Okun Memorial Lecture: "It seems clear that if we are to get out of the present impasse we must begin by constructing a different kind of abstract model, one that recognizes from the beginning that time is a continuing and irreversible process; that it is impossible to assume the constancy of anything over time, such as the supply of labour or capital, the psychological preferences for commodities, the nature and number of commodities, or technical knowledge" (Kaldor, 1985, p.61). The author argues essentially that in a complex dynamic system new forms of unexpected (including unstable) behaviour may emerge out of dissipative structures, as a result of self-organizing or learning processes. It may thus be concluded that the emergence of qualitatively new structures and trajectories in spatial–economic systems may be at odds with traditional spatial–economic equilibrium modelling which is based on stable structures over a relevant system's domain.

To cope with these issues of dynamic specification of spatial–economic models due attention has to be given to flexible mathematical forms, but even more to qualitative (including organizational/topological) structures in the space–economy (such as culture, education, the state of technology, institutional constellations) with a mix of slow and fast dynamics including positive and negative feedback conditions. Against this background the notion of interactive economic analysis is highly relevant (Morishima, 1991) and fits in the current fashion to introduce evolutionary concepts in economic thinking.

6. The methodology of spatial economics revisited

The previous thoughts have addressed the limitations of *ceteris paribus* conditions in (spatial–)economic analysis. Clearly, in a rather static situation this is a perfectly acceptable position which has demonstrated its great relevance in a long (spatial–) economic research tradition. In a highly dynamic context, with complex space–time system's interactions, stable solution trajectories are less likely to occur. Consequently, alternative methodological departures may then have to be envisaged. In particular, approaches based on evolutionary ecology (see *e.g.* Nelson, 1995) may be deployed to analyse social, technological and spatial–economic dynamics where concepts like diversity, interaction, resilience, adaptivity, self-organisation, learning and niche formation play a prominent role and where multi-layer structures with dynamic interaction in a niche form can produce a variety of dynamic behaviour such as cycles, fluctuations and bifurcations in relation to structural changes in the space–economy.

For the analysis of complex spatial–economic systems new methodological tools may be needed. Clearly, specification theory is still the heart of (spatial–)economic modelling, but complementary tools may be needed, such as interactive computer simulation of prototype partial differential equations (see Nijkamp and Reggiani, 1998). From an empirical perspective, when large data sets on complex spatial–economic phenomena are available, the use of artificial intelligence techniques for adaptive systems (see *e.g.* Bak, 1996) may provide promising departures. Computational neural network methods, evolutionary adaptive learning principles or self-organised criticality analysis have provided novel frameworks that offer a great scope for an operational analysis of complex systems and that offer also a meaningful scope for prediction experiments (see *e.g.* Reggiani and Schintler, 2005).

The validation of the correct specification of complex spatial–economic models is fraught with many uncertainties, as the law of Tobler (1970) indicates that in the space–economy everything is linked to everything else. Thus, a partial testing is problematic and therefore most researchers resort to computer simulation to investigate the robustness of systemic variables in a space–time context. In this context, counterfactual analysis may be helpful (see McCloskey, 1991 or Lewis, 1973). Counterfactuals are computer-experimental approaches to trace the development of a complex system under 'what if' conditions that are different from its actual territorial trajectory. Counterfactual analysis has also already a long history in economic research (see *e.g.* the description of imaginary construction by Von Mises (1949) or the counterfactual historiography of novel laureate Fogel, 1964). More recently, the increase in computational capacity has allowed researchers to perform more rigorous qualitative tests on causal patterns in complex systems. Retracking histories under varying initial conditions may bring us mathematically in the realm of chaos theory, but in the empirical statistical world the use of genetic algorithms may be more helpful to identify sensitivity areas (*e.g.* bifurcation points) in a dynamic spatial–economic system.

The analysis of possible alternative trajectories of a complex system brings us also in the realm of value transfer (see Bal and Nijkamp, 2002; Nijkamp, 2005). Value transfer is an approach originating from and associated with quantitative research synthesis in meta-analysis (Roberts, 2005). Value transfer assumes that any complex phenomenon may be influenced by site-specific variables and general moderator variables. By analysing in detail – *via* numerical statistical methods, meta-regression techniques or simulation experiments – the relative impact of the site-specific variables, it may be possible to transfer the system's model concerned to another situation (often called the policy site) in order to identify the size of the site-specific variables in this new site with a view to the prediction of the complex phenomenon at hand in this hitherto unexplored situation. Clearly, value transfer may be linked to both computer experimentation of complex data sets and to linear or nonlinear meta-regression models.

Spatial economics has built up a respectable analytical tool box. The 'new' dynamics movement has highlighted the need for complementary analysis frameworks, where the fruits of the past (*e.g.* specification theory, micro-based behavioural analysis) are to be combined with new research departures, such as endogenous evolutionary analysis and computational experimentation of complex large data sets.

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